30 October 2007

To Whom It May Concern:

The Discovery Channel (DC) is airing a four part series called Storm Chasers (SC) and another two episodes called, tentatively, The Science Behind The Storms.

The Center for Severe Weather Research (CSWR) worked with DC during the spring 2007 tornado season as they made these shows. We collaborated with Sean Casey who fielded the Tornado Intercept Vehicle (TIV). We fielded the Doppler On Wheels 3 (DOW3) and an SUV called SCOUT, the crew of which deployed several instrumented platforms called PROBES.

We have received varied feedback, nearly all positive, concerning the show. Some have asked questions in various venues concerning aspects of the show. We attempt to answer some of those below. These are our opinions, not those of DC or their production company.

1. Editorial questions concerning SC.

DC and the production company that DC hired to produce SC have total editorial control over SC. CSWR has none. CSWR has complete control over the science missions, instrument design, and the collected data. These are good boundaries. CSWR doesn't know about entertainment and DC doesn't know about tornado science.

Fundamentally, SC is entertainment; it is not a documentary; it is not a class. You should no more watch this show to learn about tornado kinematics than you would watch Deadliest Catch to learn about crab biology. The show documents what it was like for the DOW/TIV/SCOUT team to conduct their missions during the 2007 tornado season.

The Science Behind Storm Chasers shows will, we believe, have more of a documentary feel. Of course, since we do not control the content, those shows could evolve in different directions.

As entertainment, liberties are taken with the arrow of time, and latitude is taken playing up personal dynamics. DC is not making a show to educate students, or to appease storm chasers. It is making a show that will sell commercials and as such it is designed to maximize entertainment value. We hope that people will enjoy the show in this context.

2. The nature of DC - CSWR collaboration, and its positive impact on science:

DC paid CSWR for the right to follow and film the DOW and SCOUT/PROBE teams and for access to us for interviews. DC supported much of the field costs of these missions.

DC did not in any way determine missions, mission design, instrument design, or targets.

While the DOWs themselves, Rapid-Scan DOW development, and various non-tornado missions using DOWs (e.g. IHOP, MAP, JAWS-Juneau, COPS) have been government funded during the past several years, DOW tornado missions have not.

Non-traditional funding, such as that obtained this year from DC, has allowed CSWR to conduct its tornado science field studies during this period. As measured by publications in 1st tier formal refereed journals, non-traditional funding has resulted in data sets that have contributed significantly to tornado science. The following recent articles have used DOW data acquired during non-traditionally funded field programs:

Frame, J., P. Markowski, Y. Richardson, J. Straka, J. Wurman, 2007: Polarimetric and dual-Doppler Radar Observations of the Lipscomb County, Texas supercell thunderstorm on 23 May 2002, *Submitted to Mon. Wea. Rev.*

Marquis, J., Y. Richardson, Wurman, J**.**, P. Markowski, 2007: Dual- and Single-Doppler Analysis of a Tornadic Vortex and Surrounding Storm-Scale Flow in the Lowest Few Kilometers of a Supercell, *Submitted to Mon. Wea. Rev.*

Majcan, M., P. Markowski, Y. Richardson, D. Dowell, Wurman, J., 2007: Multi-Pass Objective Analyses of Doppler Radar Data, *Submitted to J. of Atmos. Ocean. Tech.*

Kosiba, K., R.J. Trapp, J. Wurman, 2007: An Analysis of the Axisymmetric Three-Dimensional Low Level Wind Field in a Tornado Using Mobile Radar Observations, *Accepted*, *Geo. Res. Let.*

Wurman, J**.**, Y. Richardson, C. Alexander, S. Weygandt, P.-F. Zhang, 2007: Dual-Doppler and Single-Doppler Analysis of a Tornadic Storm Undergoing Mergers and Repeated Tornadogenesis, *Mon. Wea. Rev.,* **135***, 736-758.*

Wurman, J**.**, Y. Richardson, C. Alexander, S. Weygandt, P.-F. Zhang, 2007: Dual-Doppler Analysis of Winds and Vorticity Budget Terms Near a Tornado, *Mon. Wea. Rev.,* **135***, 2392-2405.*

Wurman, J., C. Alexander, P. Robinson, Y. Richardson, 2007: Low Level Winds in Tornadoes and Potential Catastrophic Tornado Impacts in Urban Areas, *Bull. Amer. Meteor. Soc., **88**, 31- 46.*

Beck, J.R., J. Schroeder, J. Wurman, 2006: High-Resolution Dual-Doppler Analyses of the 29 May 2001 Kress, Texas, Cyclic Supercell, *Mon. Wea. Rev.,* **134***,* 3125-3148.

Lee, W.-C., and J. Wurman, 2005: The diagnosed structure of the Mulhall tornado, *J. Atmos. Sci.,* **62***, 2373-2393.*

Wurman, J., and C. Alexander, 2005: The 30 May 1998 Spencer, South Dakota Storm. Part 2: Comparison of Observed Damage and Radar-Calculated Winds in the Supercell Tornadoes, *Mon. Weather Rev.*, **132**, 97-119.

Alexander, C., and J. Wurman, 2005: The 30 May 1998 Spencer, South Dakota Storm. Part 1: The Structural Evolution and Environment of the Supercell Tornadoes, *Mon. Weather Rev.*, **132**, 72-96.

Dowell, D., C. Alexander, J. Wurman, and L. Wicker, 2005: Centrifuging of scatterers in tornadoes, *Mon. Weather Rev.,* **133***, 1501-1524*

Shapiro, A., P. Robinson, J.Wurman, J. Gao, 2003: Single-Doppler Velocity Retrieval with Rapid-Scan Radar Data. Journal of Atmospheric and Oceanic Technology, **20**, 1758–1775.
Wurman, J., 2002: The Multiple-Vortex Structure of a Tornado, *Wea. and Forecasting*, **17**, 473-505
Burgess, D. M. Magsig, J. Wurman, D. Dowell, and Y. Richardson, 2002: Radar Observations of the 3 May 1999 Oklahoma City Tornado, *Wea. and Forecasting*, **17**, 456-471.

In addition, several PhD and MS dissertations/theses have focused on data collected with non-traditional funding.

3. DOW and SCOUT crew members

CSWR employs the best crew that it can obtain every season. Our crew consists, largely, of meteorologists, sometimes technicians/engineers, and others who have proven useful and dependable. Most positions are filled with individuals who have not only extensive severe weather experience, but advanced degrees in meteorology. Every science vehicle had at least one crewmember with extensive field experience in severe storms

With respect to the 2007 crew, Herb Stein, the DOW driver, has driven a DOW since 1997 and chased for 20 years. Joshua Wurman the DOW operator and team leader, has an ScD in meteorology and has been leading DOW projects since 1995; Karen Kosiba, a DOW navigator, is a PhD student in meteorology and has been with DOW projects since 2004. Danny Cheresnick, a DOW navigator and television production vehicle navigator, has an MS in meteorology and has been with DOW projects for years and chasing for 10 years. Sean Casey, the TIV team leader, is a filmmaker but has been chasing tornadoes since the year 2000. Justin Walker, the SCOUT navigator, has navigated the DOW and SCOUT in previous years and has years of chasing experience. All of the above crew except Sean Casey have formal meteorological education.

For the 2007 season, CSWR gave DC permission to search for a crew member who would drive the SCOUT SUV. Since a skilled chaser and experienced DOW navigator, Justin Walker, would always be navigating SCOUT during missions, it was felt that the driver need not be a meteorologist. DC felt that having a woman would enliven the show. In 2006 Karen Kosiba was the SCOUT driver. However, for 2007, DC specifically wanted someone who was not experienced, who did not know storm morphology, someone for whom each severe weather experience was new, freshly exciting, even confusing and mystifying, someone who could ask the questions that the audience might be asking. DC chose Mara McFalls, a journalist. She had on-camera interview experience and filled the role excellently. Her job was to be a driver. The drivers of all chase vehicles in the crew are responsible for driving and driving alone while vehicles are in motion. Mara McFalls was a responsible driver and could deploy the heavy PROBES when SCOUT was stopped. She was a competent crew member.

4. Accuracy of facts portrayed on the show.

Reiterating a point made above, CSWR had no editorial control over the shows. However, to their credit, DC and their production company made substantial efforts to ensure that the show was accurate in much of its scientific detail. Draft versions of the show were sent to CSWR for comment. While CSWR had no formal control, most of the changes that CSWR recommended were made. Some details were stretched for the sake of drama, timelines were altered and simplified, but generally not ones that were significant scientifically.

Some questions have arisen concerning the specifics of the TIV intercept of the Seward, Kansas tornado and the intensity of the winds. We address these below.

The tornado that occurred near Seward, Kansas after dark had a very complex and rapidly changing structure. At times there were tornadic winds over a core flow region approaching one mile in diameter. There was a short period where winds over 85 m/s (190 mph) were measured by a DOW on the east side of the tornado. These measurements were taken at about 70 m AGL. Please see Wurman et al (2007) in the BAMS reference above for a discussion of how radar-measured winds at 30-200 m AGL may compare to those near the surface. Another discussion is in Wurman and Alexander (2005) in Mon. Wea. Rev. It is worthwhile to note that sometimes the TIV measures winds nearly as high as DOW measurements aloft. This was true in the tornado that passed west of Nickerson, Kansas this year, in which the TIV sampled the core flow at two different times. We are in the process of analyzing data from both of these TIV intercepts.

The TIV was not impacted by the region of the tornado containing 85 m/s. In fact, the TIV was outside the radius of maximum winds of the tornado. Was it inside what would visually be considered a tornado by chasers? No one can know since it was dark and rainy. Our DOW-based definition of tornado diameters (core flow diameter) is often much smaller than chaser or spotter-based visual impressions or damage-survey-width definitions. This is because lofted debris, condensation, and substantial damage can occur outside the radius of maximum winds. (This was likely the case in large, but non-radar measured, tornadoes such as those that occurred in Hallam, Nebraska(2004) and Greensburg, Kansas(2007) and was certainly true in radar-measured and visually spotted tornadoes such as those in Spencer, South Dakota (1998) and Oklahoma City (1999).)

The peak winds measured at 3 m AGL by the TIV were below 40 m/s. This is still quite high. While people often think they've been in "80 mph" or "100 mph" winds, actual calibrated measurements usually reveal much lower winds actually occurred at 1-3 m AGL. We are still analyzing the TIV data collected that night. The tornado's structure was very complex and contained intense sub-tornado vortices as well as portions which were, at times, less intense. At times one could have been inside portions of what the DOW-data revealed as a large tornado, while experiencing winds of ‘only’ 40 m/s. The passage of multiple sub-tornado-scale vortices complicates the interpretation of

observations by any of our surface instruments. Also, unfortunately, the DOW was moving (running away northwards towards Great Bend) during a portion of the TIV intercept, complicating navigation of the DOW data.

5. Safety of the missions.

The DOW team, and members of its staff, have participated in literally dozens of field programs, funded by NSF, DOD, FAA, DOC, USFS, other agencies, even other countries as well as non-traditionally funded missions. None of these, to our knowledge, has undergone the unusually exhaustive safety review and risk analysis that the DC-sponsored DOW/TIV missions have. Because a large private company, DC, sponsored our project, legal and liability issues loomed large. This was particularly true due to the nature of the TIV mission. An outside independent security and safety firm was hired each year to provide risk analysis. Detailed written procedures and risk management strategies were established.

The DOW/TIV team has a perfect safety record. We have never had a vehicle accident nor have we ever had a serious injury. Due in part to our perfect safety record, stretching back to 1995 for the DOW and to about 2000 for the TIV and pre-TIV team, we are able to obtain insurance both for liability and for equipment. Our crews had workers' comp. insurance and death and dismemberment insurance.

To the best of our knowledge, these extensive safety precautions and procedures are at the extreme high end of what is customarily practiced by chasers and researchers.

Additional specifics:

a. The TIV mission is tightly constrained, contractually, in writing, and requires that the DOW observe winds below various thresholds before an intercept can commence. If the TIV loses contact with the DOW the mission is aborted. If the DOW cannot confirm that winds are below certain thresholds, for whatever reason, the mission is aborted. Naturally, the TIV team may bristle at these constraints, and for the sake of drama, this is displayed prominently in the television series.

b. Yes, as a some have commented, tornadoes can change in intensity, sometimes rapidly. But, $d(V_{max})/dt$ is not infinite. And, the probability that any rapid, undetected, intensification of a tornado would exactly coincide with the moment and location at which TIV was conducting an intercept is very small. With Doppler observations in 130 tornadoes, the DOW team has a unique quantitative perspective on just how fast tornadoes can actually intensify, a perspective that is likely more quantitative than that afforded by visual observations. Winds are not 30 m/s one second and 100 m/s the next. The DOW scans through the tornado every 4-5 seconds. Furthermore, TIV intercepts can be aborted, or the TIV moved to different locations in front or to the side of an approaching tornado, if conditions become hazardous. Different intercept strategies are used depending on the intensity, size, translational speed, stability of the structure of the tornado, whether it is night or day, the road network, and visibility. The DOW can

quantitatively measure tornadic winds aloft and events which might precede tornado intensification at the surface. By using a combination of several pairs of experienced visual observers and real-time DOW data, we are excellently positioned to detect any dangerous changes in intercepted tornadoes. The probability of an injury is quite low.

It is a rare tornado, and usually only a portion of that rare tornado, which would be hazardous to the TIV. The DOW/TIV team was not at the Greensburg, Kansas tornado. But, if it had been, the DOW likely would have measured ~80 m/s winds over a broad region of the eastern side of the tornado. With that intensity of wind, at night, our safety concerns would have precluded a TIV intercept. Probably even PROBE deployments would not have been attempted. No PROBES were deployed in the Seward, KS (6 May 2007) tornado due to similar safety concerns, in that case the lack of light, substantial precipitation reducing visibility, the lack of viable escape routes, and a very large tornadic circulation containing multiple vortices.

c. The SCOUT/PROBE deployment mission profile is designed to keep the teams well away from the core flow regions of tornadoes and dangerous winds surrounding the core flow.

d. Every near-storm vehicle was required to contain a skilled chaser/meteorologist as a dedicated navigator. So, while the driver of SCOUT was a journalist, there was no compromise in safety.

e. Every vehicle contained navigation systems and had communication systems to stay in contact with the DOW. Every vehicle carried a satellite phone in case it got marooned at night and was lost. Every vehicle had a first aid kit and emergency supplies such as water, food, and road flares.

f. The field team was accompanied by a dedicated medical officer riding in a separate non-science, non-TV-production vehicle.

g. The medical officer's vehicle carried an automatic defibrillator, a back board, and other specialized emergency medical equipment.

We are not aware of any other research teams, tour operators, individual storm chasers who go to nearly these extremes related to safety.

6. Value of the DOW, TIV and PROBE science

By definition, non-traditionally funded missions have not been funded by a science agency. Typically, they have not been peer reviewed by scientists. So, compared to a peer reviewed field research project such as VORTEX or VORTEX2, it is fair to question whether the missions are scientifically valuable.

The TIV has been instrumented to record wind speed and direction, as well as temperature and relative humidity. Two calibrated anemometers, one ultrasonic and the

other a standard RM Young, are mounted at 3-m AGL. The T/RH sensor is aspirated and shielded. Data are recorded every second to a Campbell data logger. GPS locations are logged. This instrumentation allows for data to be collected in the environment very near to a tornado, as well as inside a tornado. High quality, calibrated, archived T, RH, and Wind observations, in and immediately adjacent to tornadoes, are virtually non-existent in the scientific community. Thus, while the TIV is on its mission to capture film of a tornado, it also functions to collect meteorological data which has been extremely difficult to attain previously. SCOUT is instrumented similarly to the TIV, so the PROBE deployment missions result in meteorological observations of T, RH and winds near the tornado, also at 3-m AGL.

The PROBES themselves are similarly instrumented and collect T, RH, and dual wind measurements at 1-m AGL, both adjacent to and, if well placed, inside tornadoes.

In situ data proximate to and in tornadoes are important to understanding tornado kinematics and tornadogenesis and evolution. Some of these needs are discussed in the VORTEX2 Scientific Program Overview (SPO) document that is linked to the VORTEX2 web site at www.vortex2.org.

Combined DOW/TIV data have appeared in a peer reviewed, 1st tier, formal publication. Wurman et al. 2007 (full BAMS reference listed above) used a combination of DOW and TIV data to study the winds in the 3-m to 200-m AGL region of tornadoes. CSWR is analyzing 2007 DOW, TIV and PROBE data and plans to submit analyses for formal publication in a year or so. DOW data have appeared in many publications, as listed above.